Rationale for rule making option to require 16/0 circle hooks in tuna directed pelagic longline fisheries to mitigate sea turtle mortality.

John Watson, Sheryan Epperly, Lance Garrison, Arvind Shah, and Charles Bergmann
NOAA National Marine Fisheries Service
Southeast Fisheries Science Center
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NOAA Fisheries has completed 3 years of research in the Western Atlantic Ocean, developing and evaluating sea turtle mitigation measures to reduce the mortality of sea turtles taken incidentally in the swordfish directed pelagic longline fishery. Based on the 2002 experiments, we have determined that the use of 10 degree offset or less 18/0 circle hooks and/or the use of mackerel bait significantly reduces the interaction of sea turtles (Watson et al., in prep.). Relative to the 9/0 "J" hook baited with squid, the combination of 18/0 circle hooks and mackerel bait reduced loggerhead interaction rate by 90% (CI = 70%-97%, $p < 0.0001$) and leatherback interaction rate by 65% (CI = 36%-81%, $p = 0.0007$) with no negative effect on swordfish catch. The 18/0 circle hooks baited with squid reduced loggerhead interaction rate by 87% (CI = 73%-93%, $p < 0.0001$) and leatherback interaction rate by 57%, CI = 34%-72%, $p < 0.0001$), but swordfish catch rate was reduced by 29-33%. The use of mackerel bait significantly reduced the catch rate of bigeye tuna (81% CI = 49%-100%, $p < 0.0001$) and squid with circle hooks had a nominal increase in bigeye tuna catch. The 2003 experiment was completed in November and the data will be analyzed by the end of December 2003. In addition to 18/0 circle hooks with squid and mackerel, 20/0 (10 degree offset) circle hooks with mackerel were evaluated in 2003. Preliminary results indicate turtle bycatch reduction rates similar to 2002 for loggerhead and leatherback turtle interactions with 18/0 circle hooks and mackerel bait and even higher reduction rates with the 20/0 circle hook.

Also, in anticipation of the need for mitigation measures in tuna directed fisheries, research was initiated late in 2003 comparing 16/0 circle hooks with 18/0 circle hooks, but only a small number of sets (n=29) could be completed due to the sample sizes required for the other treatments in the swordfish fishery, which was our first priority. While we expect that the 18/0 hook will reduce bycatch of loggerhead turtles over the 16/0 circle hook for NED-size turtles, we do not know yet what effect the 16/0 circle hook will have on leatherback bycatch nor on the target species catch. Very preliminary results are consistent with a reduction in the bycatch of loggerheads (13 caught on 16/0 vs 4 caught on 18/0). There was less of a change in leatherback bycatch (3 vs 0 caught). On these sets, tuna catches, in numbers were not substantially affected by the hook treatment (149 vs 136 bigeye and 85 and 85 yellowfin (marketable fish) on 16/0 and 18/0 hooks, respectively). Total weight of marketable yellowfin tuna was 4062 lbs (16/0) and 4280 lbs (18/0). Preliminary analysis of the NED data indicates that there was no significant difference in the catch rates for yellowfin tuna for the 16/0 and 18/0 hooks for either numbers or weight of fish ($p = 0.8197$ and $p = 0.9109$ respectively). The sample size is very small, however, and the power of the existing data to detect a 10% difference in the catch rates is only 15% and only 38% to detect a catch rate difference of 20%. Until we have a sufficient sample size comparing the 16/0 and 18/0, or larger hooks, it may be not advisable to require a hook larger

than the 16/0 circle hook throughout all the pelagic longline fisheries if the hook currently in use in part of the U.S. tuna fishery and other tuna fisheries worldwide (16/0 circle hook), can achieve the needed sea turtle bycatch reduction. A larger hook could impact the target species catch and we do not know what that effect will be. Once we determine that effect, we could make an informed decision on requiring even larger hooks in the fishery.

HMS has requested information available on the effects of 16/0 circle hooks on target catch and the effectiveness of 16/0 circle hooks in reducing loggerhead and leatherback turtle interactions. There are several sources of information available to assess the potential impact of 16/0 circle hooks in the tuna directed pelagic longline fishery. In addition there is the experience and knowledge of fishery experts and gear technologists. We have summarized the information available by species.

Loggerhead Turtles

Relative to "J" hooks, circle hooks improve the probability of survival after the interaction because they usually hook animals in their jaw and the hooks are not swallowed; this appears to be true for many marine species and circle hook sizes (Lucy and Studholme 2002). Whether circle hooks also effectively reduce the number of interactions appears to be a function of the size of the circle hook and the size of the animal (Watson et al. 2003). The effect of 16/0 circle hooks baited with squid was evaluated in the Azores pelagic longline fishery in 2000 and 2001 (Bolten et al. 2002). They found no difference in the loggerhead interaction rate between 16/0 non offset circle hooks and 9/0 non offset "J" hooks, but did find a significant difference (Chi-square test, $p < 0.001$) in the hooking location between the "J" hooks and circle hooks. They found that 53 % of turtles were caught in the throat with the 9/0 "J" hook compared to only 8% with 16/0 circle hooks (interactions with circle hooks were more likely to result in mouth hooking); they stated "this difference may have important implications for sea turtle mortality". In a Canadian study (Javitech Ltd. 2002), most hardshell turtles were caught during the fall during the tuna directed season using 16/0 circle hooks. They reported that 92.5% of the turtles caught were hooked in the mouth and only 4% swallowed the hook. This is consistent with our results from our NED 2002 and 2003 experiments where we found that turtles caught on the "J" hooks swallowed significantly more hooks than turtles caught on 18/0 or 20/0 circle hooks (Watson et al. in prep.; unpubl. data); turtles caught on circle hooks were predominantly hooked in the mouth. We would conclude, therefore, that circle hook caught turtles would have a higher survival rate than "J" hook caught turtles.

While neither the Azores study nor the Canadian study found a difference in interaction rates between a 9/0 "J" hook and a 16/0 circle hook (Bolten et al. 2002; Javitech 2002), a summary of U.S. pelagic longline observer data from the Gulf of Mexico, 1992-2002, indicates "J" hooks had a higher average catch rate of marine turtles than circle hooks (Garrison 2003b); in fact no loggerhead turtles have been observed captured on circle hooks in the Gulf of Mexico (65 % of sets using circle hooks used 16/0; 32% used 15/0; the number of sets observed using circle hooks = 416).

Leatherback Turtles

Leatherback turtle interactions are primarily foul hooking, usually in the flipper, shoulder, or armpit. Circle hooks reduce the number of turtles foul hooked by pelagic longline gear over the catch taken on "J" hooks. The NED experiments demonstrated this for 18/0 and 20/0 circle hooks (Watson et al. in prep.; unpubl. data). A summary of U.S. pelagic longline observer data from the Gulf of Mexico, 1992-2002 indicates "J" hooks had a higher average catch rate of marine turtles than circle hooks (Garrison 2003b). Predominant hook sizes used by the fishery were 15/0 and 16/0 circle hooks and 7/0 and 8/0 "J" hooks. Sets using "J" hooks primarily used squid and sets with circle hooks primarily used fish baits. Estimates of leatherback turtle bycatch in the GOM (Garrison 2003a) have increased in recent years and that increase has been associated with an increase proportion of the fishery using J hooks and squid baits (Garrison 2003b). The reduction in leatherback bycatch is due to the design of the circle hook which has the hook point turned in toward the shank of the hook thus protecting the hook point from foul hooking. It is also due to the fact that the circle hooks we tested do not have an extreme offset. Most of the data available is for 18/0 and 20/0 hooks from the NOAA Fisheries Western Atlantic research program, but there is every reason to expect the 16/0 circle hook to be just as efficient in reducing foul hooking. The gap between the hook point and the shank is even smaller for the 16/0 than for the tested 18/0 and 20/0 hooks, which should make it at least as efficient in reducing foul hooking as the 18/0, and perhaps will prove to be more efficient. In a report on sea turtle interactions in the 2001 Canadian pelagic longline fishery, leatherback turtle interactions were reduced from rate of 0.2205 leatherbacks foul hooked per 1,000 hooks with offset "J" hooks to 0.0127 per 1,000 hooks with 10 degree offset 16/0 circle hooks. Although not all hooking locations were reported 11 of 12 turtles reported were foul hooked and only 4 turtles were not reported so that even if we assume that the additional 4 turtles were not foul hooked the total would be 11 out of 16 foul hooked. In the Canadian fishery the bait used with circle hooks was squid and the bait used with "J" hooks was mackerel. We would expect an even larger reduction in the GOM comparing 16/0 circle hooks with squid and "J" hooks with squid because mackerel bait alone had a significant reduction in leatherback interactions in the NED research.

Tuna

The 16/0 circle hooks are becoming more widely used in the U. S. and Canadian directed tuna fishery, indicating they perceive circle hooks more effective for tuna directed fisheries. Circle hook use in pelagic longline fisheries may increase the catch per unit effort (CPUE) of yellowfin tuna and improve the survival of incidental fish bycatch (Falterman and Graves 2002). The average catch rates of yellowfin and other tuna species in the Gulf of Mexico are higher with circle hooks, which are primarily 15/0 and 16/0 sizes (Garrison 2003b). We have no data on the use of 18/0 circle hooks in the tuna directed fisheries outside of the Western Atlantic Northeast Distant Waters (NED). Limited data from the NED show no loss in yellowfin tuna catch with 18/0 hooks compared to 16/0 but the sample size (31,690 hooks) is too small to conclude that there is no difference in the catch. A power analysis controlling type I error at 0.10 and type II at 0.20 (power = 0.8) indicates that a sample size of 124,5210 hooks would be required to detect a 20% difference in catch and a sample size of 563,744 hooks would be

required to detect a 10% difference in catch. The bait used in the NED was squid and the primary baits used in the GOM with circle hooks are sardines and herring. The difference in bait types and gear configurations between the GOM and Atlantic fisheries could affect the tuna CPUE's and the effectiveness of 16/0 versus 18/0 circle hooks. In the Gulf of Mexico, small fish bait (sardines and herring) had a higher catch rate for yellowfin tuna than squid bait (Garrison 2003b). Large fish bait (mackerel) used in the NED experiments significantly (81%) reduced bigeye tuna catches (Watson et al. in prep.).

Mahi Mahi

Catch of mahi mahi is an important component of the tuna directed fishery. The primary hook used in the U.S. directed mahi mahi fishery is the 14/0 circle hook. While we have no data on the effect of 18/0 circle hooks on mahi mahi, it is our opinion that the 18/0 circle hook will likely have a significant effect on mahi mahi catch rates in the tuna directed fisheries.

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HMS List of Options with SEFSC comments:

1. **16/0 offset with mackerel bait**

We do not have any data on 16/0 circle hook with mackerel bait. It will be difficult to bait 16/0 circle hook with mackerel bait of the size evaluated for the swordfish directed fishery in the NED using 18/0 circle hooks. While mackerel bait between 200 and 500 gram weight has demonstrated very good reduction in turtle interaction rate, there was an 81% reduction in bigeye tuna catch in the NED and we would expect similar reductions in yellowfin tuna catch.

Another option is 16/0 with small fish (sardines and herring) and there is some evidence from GOM observer data that there could be a reduction in loggerhead interactions. It is difficult to estimate the CPUE for this option, but it would probably be less than with mackerel (71%) and more than with squid (0%). Leatherback reduction with 16/0 and small fish would likely be similar to 16/0 with squid or higher.

2. **16/0 offset with squid**

CPUE for Leatherback – We would expect, based on the information available, that the CPUE for leatherback turtles would be similar to the 18/0 circle hook with squid from the NED research. Based on the CPUE for leatherback takes (per 1,000 hooks) from observer data in the GOM in 2002 (0.2371 (Garrison 2003a)) we would estimate the CPUE for 16/0 offset circle hook with squid would be 0.1019 (57% reduction in CPUE based on NED data for 18/0 circle hook with squid bait) or lower based on the NED and Canadian data and our knowledge of the mechanism for leatherback reduction with circle hooks.

CPUE for loggerhead - Based on available data we would expect the CPUE for Loggerheads to be similar to 9/0 "J" hooks but with large proportion (over 50%) to be mouth hooked versus gut hooked. CPUE is estimated at 0.0579 or lower based on observer data in the GOM in 2002 (Garrison 2003a). Since the primary hooks were 7/0 and 8/0 "J" hooks in the GOM we would expect the CPUE to be lower for 16/0 circle hooks because our reduction rate proxy (18/0 circle hooks) was compared to 9/0 "J" hooks.

Change in target catch:
Swordfish – We would expect a slight reduction in swordfish catch.
Yellowfin tuna – We would expect no reduction in catch of yellowfin tuna.
Bigye tuna - We would expect no reduction in catch of bigeye tuna.

3. **16/0 non-offset with squid**

CPUE for Leatherback – We would expect, based on the information available, that the CPUE for leatherback turtles would be similar to the 18/0 circle hook with squid from the NED research. Based on the CPUE for leatherback takes (per 1,000 hooks) from observer data in the GOM in 2002 (0.2371 (Garrison 2003a)) we would estimate the CPUE for 16/0 offset circle hook with squid would be 0.1019 (57% reduction in CPUE based on NED data for 18/0 circle hook with squid bait) or lower based on the NED and Canadian data and our knowledge of the mechanism for leatherback reduction with circle hooks.

CPUE for loggerhead - Based on available data we would expect the CPUE for Loggerheads to be similar to 9/0 "J" hooks but with large proportion (over 50%) to be mouth hooked versus gut hooked. CPUE is estimated at 0.0579 or lower based on observer data in the GOM in 2002 (Garrison 2003a). Since the primary hooks were 7/0 and 8/0 "J" hooks in the GOM we would expect the CPUE to be lower for 16/0 circle hooks because our reduction rate proxy (18/0 circle hooks) was compared to 9/0 "J" hooks.

Change in target catch:
Swordfish – We would expect a slight reduction in swordfish catch.
Yellowfin tuna – We would expect no reduction in catch of yellowfin tuna.
Bigye tuna - We would expect no reduction in catch of bigeye tuna.

Addendum

Evaluation of 18/0 Circle Hook in the Gulf of Mexico Directed Tuna Fishery
June 22, 2004

NOAA Fisheries, Southeast Fisheries Science Center conducted experiments in the Gulf of Mexico from February through April, 2004 on cooperative commercial pelagic longline vessels in the directed tuna fishery. The objective of the research was to compare 0° offset 18/0 circle hooks to 0° offset 16/0 circle hooks on directed tuna sets. Three vessels participated in the research making 7 trips fishing a total of 29,570 hooks. 18/0 0° offset circle hooks were alternated with 16/0 0° offset circle hooks using sardine bait on every set. Catch data were collected by NOAA Fisheries observers.

Three leatherback turtles were caught during the experiment; 2 on the 18/0 circle hooks (cpue = 0.13 per 1,000 hooks) and 1 leatherback on the 16/0 circle hooks (cpue = 0.068 per 1,000 hooks). The sample size was too small to detect any significant difference between the hook types for leatherback turtles. The observed cpues for leatherback turtles were much lower than reported by Garrison, 2003a from observer data in the GOM in 2002 (cpue 0.237 per 1,000 hooks), which we would expect with an industry switch from "J" hooks to circle hooks. All three leatherback turtles were fouled hooked and were released alive. Although the hooks were not removed, the line remaining on the turtles at release was less than ½ the carapace length in each case. No loggerhead turtles were caught.

Three hundred and forty seven yellowfin tuna were caught on 16/0 circle hooks (cpue = 0.0235) and 250 yellowfin tuna were caught on 18/0 circle hooks (cpue = 0.0169). There was a 26.5% reduction in total yellowfin tuna caught on the 18/0 circle hook compared to the 16/0 circle hook which was statistically significant ($p = 0.0025$). The cpue for marketable yellowfin tuna by weight caught on the 18/0 circle hook was 1.07 lbs/hook and 1.44 lbs/hook for the 16/0 circle hook. There was a 25.7% reduction by weight for marketable yellowfin tuna caught on 18/0 circle hooks compared to 16/0 circle hooks which was statistically significant ($p = 0.02$). The above p values were computed using paired t-test on catch per unit hook for each set. These p-values are in agreement with those from fitting the model with total catch as the dependant variable and number of hooks and treatment as independent variables. These results indicate that requiring 18/0 circle hooks in the directed tuna fishery will likely result in substantial economic loss to the fishery.